Report for 2005TX190B: Evaluation of Standards for Compost Blankets in Stormwater Control

Publications

- There are no reported publications resulting from this project.

Report Follows

Evaluation of Standards for Compost Blankets in Stormwater Control-Part 1: Interrill Erosion and Runoff

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ABSTRACT: *Runoff rates, solid detachment, and interrill erodibility rates were determined and compared across seven blanket treatments applied at 5 cm and 1.3 cm depth. An indoor rainfall simulator was used to apply an average rainfall intensity of 92 mm/hr to aluminum pans with each treatment at a 3:1 slope. The mean runoff for CMT-1.3, CMT-5, and TS treatments were similar whereas, the mean runoff for HS, ECC-5, ECC-1.3, and GUC-5 were similar in values. The log-transformed geometric means of interrill erodibility resulted in CMT-1.3, CMT-5, and TS treatments had similar means whereas, the mean runoff for HS, ECC-5, ECC-1.3, and GUC-5 were similar in values. The interrill erodibility had the same mean comparison results as the runoff rates. Overall, the depth of application had no significant affect on the runoff, detachment, or interrill erodibility. Yet, coarser materials (i.e. woodchips and hydro seeding), absorb reduced the amount of runoff and minimized detachment and interrill erodibility.*

KEYWORDS: Compost blankets, detachment, interrill erodibility

OBJECTIVES

The overall objective of this study was to determine the effectiveness of using compost rather than the conventional hydroseeding application to reduce erosion and nutrient load from roadside construction. Blanket applied compost was used in seven treatment applications at 5 cm and 1.3 cm depths for this research. The treatments were: untreated woodchips, composted yard trimmings, topsoil, and fertilizer-paper mulch blend as the hydroseeding. Runoff rates, solid detachment, and interrill erodibility rates were determined and compared across the six treatments. The specific objectives of the study were:

- Determine the effect of treatment on runoff rate, detachment, and interrill erodibility

- Determine the optimal application depth of compost to minimize runoff from treatment plots.

LITERATURE REVIEW

In 1987, the Clean Water Act was revised to require all states to investigate non-point sources of sediment and determine strategies to minimize the sources. Currently, the United States Environmental Protection Agency (EPA) regulates stormwater from construction activities as part of the National Pollution Discharge Elimination System (NPDES) (US EPA, 1995). The Texas Department of Transportation (TxDOT) has approved and promoted the use of compost as stormwater BMPs during highway construction. Recent studies have shown that compost application will reduce erosion (Persyn et al., 2004; Demars et al., 2000; Storey et al.,1996), improve re-vegetation (Richard et al., 2003), and minimize costs for construction companies (TxDOT, 2004).

Composting is a process of breaking down organic materials into an aerobic biodegradable blend (EPA, 1995). Compost is typically applied one of the three ways for erosion control; incorporated with topsoil, as a blanket, or as a filter berm.

Mukhtar (2004) conducted a study on the effects of using dairy manure compost for controlling erosion and revegetation on steep slopes. They reported that dairy manure compost resulted in less runoff with fewer total solids than a commercial fertilizer. They recommended manure compost be applied to highway construction for erosion control.

Persyn et al. (2004) studied erosion along Iowa highways using three different composts blanket; biosolids compost, yard waste compost, and bio-industrial compost, applied at 5 cm and 10 cm depths. The report sited mulch blanket compost at the 5 cm application as an efficient application to reduce runoff and erosion.

Interrill erosion is the amount of sediment is detached from surface after rainfall impact. Recent work by Persyn et al. (2004) as developed for the Water Erosion Prediction Project model to describe interrill erosion mechanics is shown below.

$$D_i = K_i I q S_f \qquad (3)$$

where

D_i =steady-state interrill erosion rate (mass of soil eroded/unit area/unit time)

K_i =interrill erodibility (mass-time/length^4)

I=rainfall intensity (depth/unit time)

q=runoff rate (depth of solids eroded/time)

$S_f = 1.05 - 0.85\exp(-4\sin\theta), \theta$ is the slope angle (unit-less)

The steady-state interrill erosion rate, D_i , equals the weight of sample collected divided by the surface area of the aluminum pan divided by the time interval of each sample collection. The rainfall intensity, I, was determined by averaging the five rain depths taken within 60 minutes. The slope factor, S_f, is calculated using 18.43 as the angle for theta. Interrill erodibility was then calculated for each sample (Eq. 4).

$$K_i = D_i / I q S_f \qquad (4)$$

METHODS AND MATERIALS

The experiment was conducted in the Water Quality Laboratory at the Department of Biological and Agricultural Engineering at Texas A&M University. An indoor rainfall simulator was used in an effort to control both rainfall intensity and climatic conditions.

Experimental Design

The aluminum soil pans were built using NSERL Hydraulics Lab specifications (Norton et al., 1996). The height, width, and length dimension for each pan was 0.2 m (8 in.), 0.33 m (13 in.), and 0.45 m. (18 in) respectively (fig.1).

Figure 1: Experimental Setup for treatments

Each pan was set on a 3 to 1 slope. Four layers were placed in each aluminum soil pan; gravel, fabric, topsoil, and treatment (fig. 2).

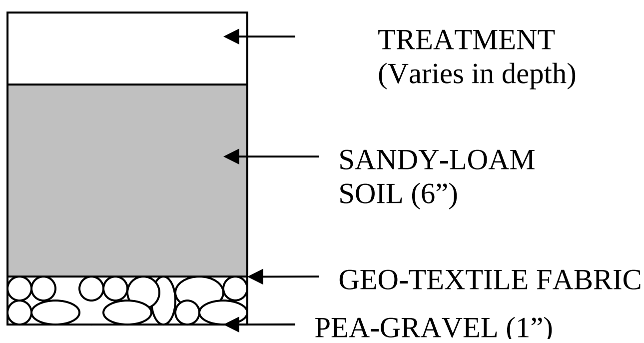

Figure 2: Plot setup for each of the six treatments

Treatments

Seven total treatments were tested: a compost/topsoil blend at a 5 cm depth, a woodchip/compost blend at 5 cm and 1.3 cm depths, 100% compost at 5cm and 1.3 cm depths and two controls (hydro seeding at a 5cm depth and topsoil at 5cm depth). Specifics on each treatment are provided in Table 1. Compost was obtained from the Brazos Valley Solid Waste

Management Authority (BVSMA) in Bryan, Texas. The BVSMA composting facility is a Seal of Testing Assurance Facility as outlined by the United States Composting Council.

Table 1: Seven treatments used in interrill erosion analysis

Treatment	Characteristic	Application
Compost Manufactured topsoil (CMT-5)	75% topsoil, 25% compost	5 cm (2 inches)
Erosion Control Compost (ECC-5)	50% untreated wood chips, 50% compost blend	5 cm (2 inches)
General Use Compost (GUC-5)	100% Compost	5 cm (2 inches)
Dispersion Treatment of Erosion Control Compost (ECC-1.3)	50% untreated wood chips, 50% compost blend	<1.3 cm (1/2 inch)
Dispersion Treatment of Compost Manufactured topsoil(CMT-1.3)	75% topsoil, 25% compost	<1.3 cm (1/2 inch)
Hydroseeding (HS)	Paper mulch with fertilizer and Bermuda grass seeds.	5 cm (2 inches)
Topsoil (TS)	100% topsoil	5 cm (2 inches)

Compost Characteristics

A chemical and physical analysis of each raw material was conducted by the Texas Cooperative Extension /Soil, Water, and Forage Testing Laboratory at Texas A&M University. A list of multi-nutrient analysis is found in Table 2 and Table 3.

Table 2: Chemical characteristics of samples

Sample ID	**pH**	**Conductivity [umho/cm]**	**Nitrate-N [ppm]**	**Phosphorus (P) [ppm]**	**Potassium (K) [ppm]**	**Calcium (Ca) [ppm]**	**Magnesium (Mg) [ppm]**	**Sulfur (S) [ppm]**	**Sodium (Na) [ppm]**
TS	7.8	81	1	3	53	974	116	9	190
TS	8.8	173	4	3	31	11051	100	12	255
CMT	7.9	250	7	190	183	2001	184	43	283
GUC	7.1	718	5	156	848	1733	279	44	326
GUC	7.2	1128	103	695	753	2802	297	129	414
ECC	6.8	1197	84	813	1032	3376	370	158	518

Table 3: Physical characteristics of samples

Sample ID	Sand [%]	Silt [%]	Clay [%]	Texture
TS	86	4	10	Loamy Sand
TS	86	4	10	Loamy Sand
CMT	86	6	8	Loamy Sand
GUC	n/a	n/a	n/a	n/a
GUC	n/a	n/a	n/a	n/a
ECC	n/a	n/a	n/a	n/a

Rainfall Simulator

The simulator was operated using specifications described by Meyer and Harmon (1979) which included using VeeJet 80100 nozzles at a height of 5m operating at a pressure of 41 kPa. Rainfall was applied at an average rainfall intensity of 92 mm/hr. A completely randomized design was selected to compare four samples of each of the seven treatments (28 treatments/sample combinations). Yet, to reduce the risk of splashing from one treatment to another, a maximum of six plots were tested under the rainfall simulator per repetition. The design was set up for seven replicates of each sample per rainfall simulation depth with at least hydroseeding or topsoil control treatment in each run, as shown in Table 4.

Table 4: Completely randomized design of the runoff

			RUNS			
1	2	3	4	5	6	7
ECC-5	TS	ECC-1.3	GUC-5	GUC-5	ECC-1.3	CMT-5
GUC-5	CMT-5	HS	CMT-1.3	CMT-5	CMT-5	CMT-1.3
TS	CMT-1.3	GUC-5	CMT-5	ECC-1.3	HS	ECC-1.3
ECC-1.3	ECC-1.3	ECC-5	ECC-1.3	ECC-5	CMT-1.3	HS
CMT-1.3	GUC-5	CMT-1.3	ECC-5	HS	ECC-5	GUC
CMT-5	ECC-5	CMT-5	HS	CMT-1.3	GUC	ECC-5

**Acronyms: GUC-5:General Use Compos (5 cm), ECC-5 :Erosion Control Compost (5 cm), CMT-5:Compost Manufactured Treatment, ECC-1.3: Dispersion Treatment ECC, CMT-1.3: Dispersion Control GUC, HS-Hydro-seeding, TS-topsoil

Data Collection

Data collection procedures were similar to those outlined in Persyn et al. (2004). Rainfall intensity of 100 mm hr^{-1} was controlled by a rainfall simulator. Five rain gauges were placed under the rainfall simulator; one at each of the four corners and another rain gauge directly in the center of the rainfall simulator distribution area. Each gauge collected rainfall for the entire 60 minutes of rain application. To analyze steady-state erodibility, samples were collected every five minutes; the first two minutes was a solid sample analysis, the next two minutes was a nutrient analysis, then a one minute break was taken. This process was repeated six times over the last 30 minutes time span with a total of 5 samples collected for solid sample analysis.

RESULTS

Statistics

The arithmetic means were computed for runoff, detachment rate, and interrill erodibility. The mean for runoff had a normal distribution and IID (Fig.3)

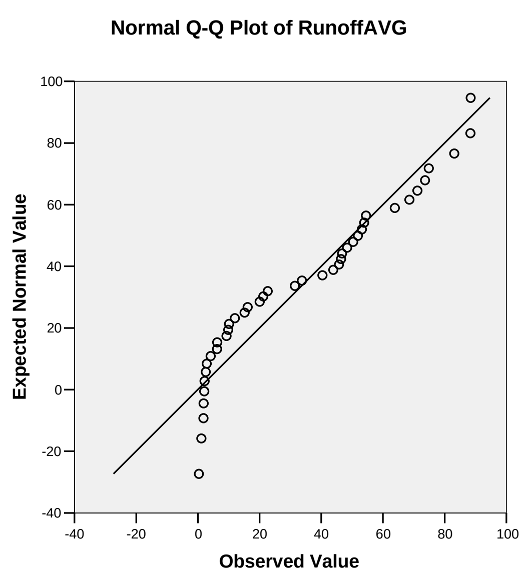

Figure 3: Normal distribution of mean runoffs using Q-Q plot

The arithmetic means of detachment and erodibility were not normally distributed, so the log-transformed geometric mean was computed for normality test (Fig. 4 and 5). To compare the difference in means for runoff, detachment, and erodibility the Analysis of Variance test (ANOVA) was computed. Using a 95% confidence interval, ANOVA tested the hypothesis of equal variances among all seven treatments.

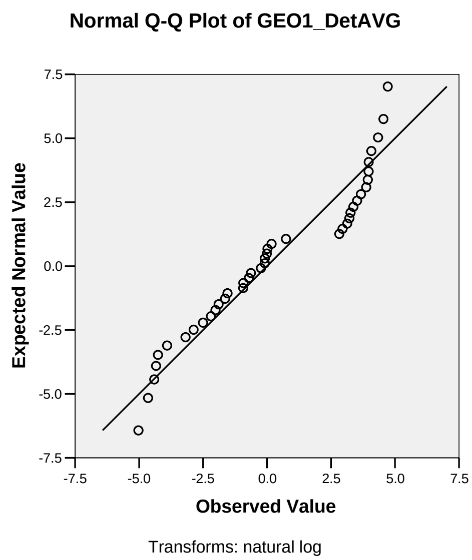

Figure 4: Log-Normal distribution of geometric mean detachment using Q-Q plot

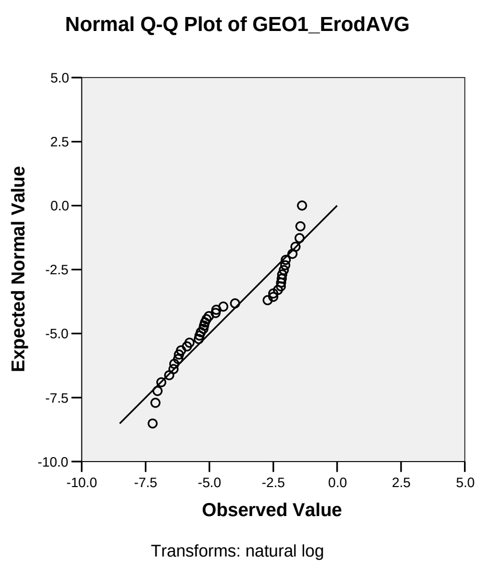

Figure 5: Log-Normal distribution of geometric mean erodibility using Q-Q plot

Runoff

Runoff was calculated using the runoff rate (mm^3/hr) divided by the surface area of the aluminum pan for all seven treatments. The arithmetic mean and standard deviation was then computed (Table 5). ANOVA determined p-values of 0.00, meaning there was significant difference in means for the runoff of each treatment.

Table 5: Arithmetic mean of runoff (mm/hr) for 5 compost treatments and 2 controls

Treatment	N	Mean	Std. Deviation
CMT-1.3	7	$61.78^{d,e,f,g}$	16.91
CMT-5	7	$65.96^{d,e,f,g}$	15.69
TS	2	$58.47^{d,e,f,g}$	14.26
HS	4	$2.44^{a,b,c}$	2.62
ECC-5	7	$13.93^{a,b,c}$	17.97
ECC-1.3	7	$18.87^{a,b,c}$	14.65
GUC-5	7	$18.55^{a,b,c}$	14.47

*Means with difference using 95% confidence interval are designated with letters. CMT1.3=a, CMT-5=b, TS=c, HS=d, ECC-5=e, ECC-1.3=f, GUC-5=g

According to Tukey's pair-wise comparison, the mean runoff for CMT-1.3, CMT-5, and TS treatments were similar whereas, the mean runoff for HS, ECC-5, ECC-1.3, and GUC-5 were similar in values.

Detachment

The detachment rate, also known as the interrill erosion rate, was determined for each treatment. Table 6 lists the geometric mean for each treatment and their standard deviation. The geometric means of zero value were considered missing values during the ANOVA, because a value of zero can not be used in calculations. Therefore, the ANOVA p-value of zero for detachment resulted in a significant difference in means for detachment rates.

Table 6: Geometric mean of Detachment (mg/m^2-sec) for 5 compost treatments and 2 controls

Treatment	N	Mean	Std. Deviation
CMT-1.3	7	42.49^{c,d,e,f,g}	32.63
CMT-5	7	44.96^{c,d,e,f,g}	20.25
TS	2	73.73^{a,b,d,e,f,g}	29.49
HS	4	0.14^{a,b,c}	0.18
ECC-5	7	0.35^{a,b,c}	0.39
ECC-1.3	7	0.69^{a,b,c}	0.78
GUC-5	7	0.41^{a,b,c}	0.40

*Means with difference using 95% confidence interval are designated with letters. CMT1.3=a, CMT-5=b,

Using the log-transformation of geometric means, the pair-wise comparison resulted in treatments CMT-5 and CMT-1.3 were similar in means, whereas HS, ECC-5, ECC-1.3, and GUC-5 were similar in means. However, the topsoil control treatment (TS) was significantly different from all other treatments.

Interrill Erodibility

The interrill erodibility was calculated for all seven treatments. The geometric mean and standard deviation were computed (Table 7). The ANOVA results concluded that all treatments were significantly different in means.

Table 7: Geometric mean of Interrill Erodibility (kg-sec/m^4)*(10^{-6}) for 5 compost treatments and 2 controls

Treatment	N	Mean	Std. Deviation
CMT-1.3	7	0.13^{d,e,f,g}	0.06
CMT-5	7	0.13^{d,e,f,g}	0.03
TS	2	0.24^{d,e,f,g}	0.02
HS	4	0.01^{a,b,c}	0.01
ECC-5	7	0.00^{a,b,c}	0.00
ECC-1.3	7	0.00^{a,b,c}	0.00
GUC-5	7	0.00^{a,b,c}	0.00

*Means with difference using 95% confidence interval are designated with letters. CMT1.3=a, CMT-5=b, TS=c, HS=d, ECC-5=e, ECC-1.3=f, GUC-5=g

Applying Tukey's pair-wise comparison for the log-transformed geometric means of interrill erodibility resulted in CMT-1.3, CMT-5, and TS treatments had similar means whereas, the mean runoff for HS, ECC-5, ECC-1.3, and GUC-5 were similar in values.

CONCLUSION

In summary, the mean comparison for runoff rates concluded the more topsoil added to the treatment increased the runoff rate. Hydro seeding resulted in the lowest runoff depth of 2.44 mm/hr. For interrill erosion (i.e. detachment) results, the topsoil had the highest detachment rate of 73.73 mg/m^2-sec. Topsoil also had the highest interrill erodibility rate of 0.24 kg-sec/m^4*(10^{-6}). Depth of application had no significant affect on the runoff, detachment, or interrill erodibility. Yet, coarser materials (i.e. woodchips and hydro seeding), absorb the impact of splashing due to interrill erosion which may have reduced the amount of runoff and minimize detachment and interrill erodibility.

FUTURE WORK

- Repeat treatment comparison for runoff rate, detachment and interrill erodibility for first flush
- Evaluate the water quality implications of using nutrient rich source materials
- Determine the rill erosion mechanics for compost blankets

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